SERIAL NUMBER _____

INSTRUCTION MANUAL

SD101A-MK III

DYNAMIC ANALYZER

(PART ONE)

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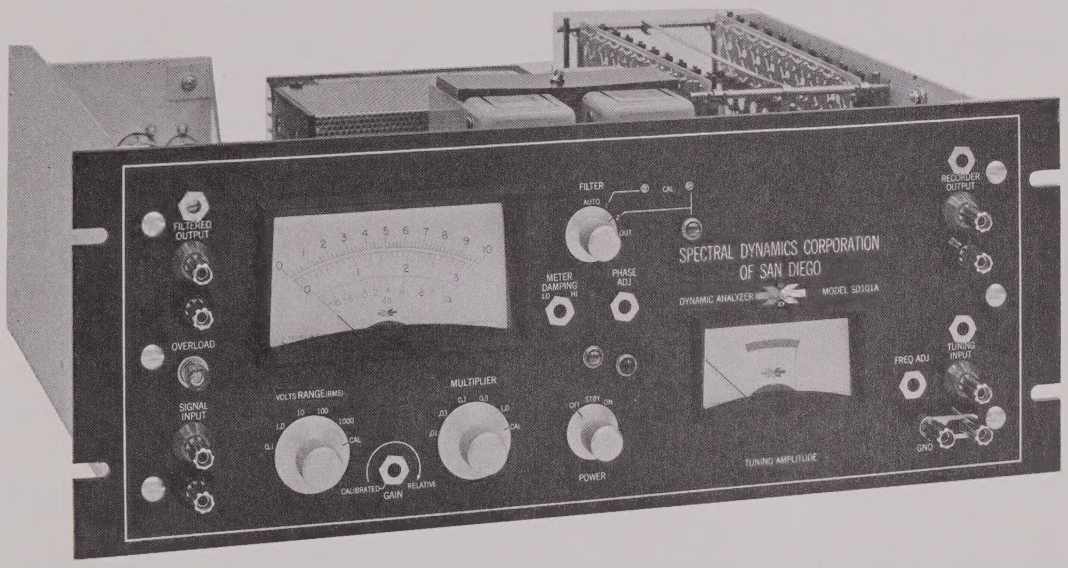


Model SD101A Dynamic Analyzer

PACKING

The Model SD101A Dynamic Analyzer is shipped fully assembled in a polystyrene carton which protects the instrument against all normal shipping hazards. To determine possible damage during shipment of the instrument, the procedures given below should be followed:

a. Place the carton upright on the floor and inspect the exterior, making note of any visible damage.

b. Remove and retain all forms and invoices attached to the carton by the carrier.

c. Unseal the top portion of the carton and remove.

d. Lift the instrument out of the carton and place it on a work bench or other flat surface.

e. Inspect the exterior of the Dynamic Analyzer carefully, noting all visible damage.

f. The Dynamic Analyzer may now be checked for functional operation by following the procedure outlined in Section II.

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report forwarded to Spectral Dynamics Corporation of San Diego. The buyer will be advised of the disposition to be made of the equipment and arrangements shall be made for repair or replacement. Include Name, Model Number and Serial Number when referring to this instrument for any reason.

WARRANTY

Spectral Dynamics Corporation of San Diego warrants each instrument manufactured by them to be free from defects in material and workmanship for one year after delivery to the original purchaser. Our liability under this warranty is limited to servicing and adjusting the instrument returned to the factory with transportation charges prepaid by the purchaser. This warranty specifically excludes any liability in regard to electron tubes, batteries, fuses and lamps. If the fault or a portion thereof is determined by us to have been caused by misuse or abnormal conditions of operation, an estimate will be submitted to the purchaser prior to starting the work on the repairs.

If any fault develops, the following steps should be taken:

1. Notify us or our representative in your area, giving full details of the problem, including name, model and serial number of the equipment. Upon receipt of this information, we will submit service data or shipping instructions.

2. On receipt of shipping instructions, forward the instrument prepaid, to the factory or authorized repair station indicated on the instructions.

SHIPPING

All shipments to the factory should be made via Air Freight. The instrument should be replaced in its original shipping carton or in a strong exterior container surrounded by two or three inches of excelsior or similar shock-absorbing material.

TABLE OF CONTENTS

(PART ONE)

Section			Page
I	GENERAL INFORMATION		
	1-1	Introduction	1
	1-2	General Description	1
	1-3	Specifications	7
II	OPERATING INSTRUCTIONS		
	2-1	Preliminary Operation Checks	9
	2-2	Operation	10
	2-3	Setting the Range and Multiplier Switches	10
	2-4	Making Relative Measurements	11
	2-5	Use of Internal CAL Signal	11
III	THEORY OF OPERATION		
	3-1	Introduction	15
	3-2	Circuit Description	20
IV	MAINTENANCE		
	4-1	General	29
	4-2	Test Points	29
	4-3	Repair and Maintenance	29
	4-4	Troubleshooting	35
	4-5	Maintenance Adjustments	35
	4-6	Frequency Response	35
	4-7	Signal Modulator Balance	36
	4-8	Carrier Converter Sideband Output Alignment	36
	4-9	Gain	37
	4-10	Calibration of Internal CAL Reference	38
	4-11	Troubleshooting Guide	39
	4-12	Troubleshooting - General	41
	4-13	Test Points & Associated Waveforms & Signal Voltage Levels	41
V	TABLE OF REPLACEABLE PARTS		
	5-1	General	47

(PART TWO)

Part II Model SD21 Automatic Bandwidth Switching Adapter Rear

LIST OF ILLUSTRATIONS

Figure		Page
1.	Concept of Operation.	1
2.	Front Panel	3
3.	Rear View	6
4.	Block Diagram Showing CAL Circuits.	12
5.	Simplified Block Diagram.	15
6.	Carrier Converter	17
7.	Balanced Modulator.	18
8.	Alignment Procedure	20
9.	Internal Calibration.	21
10.	Wideband Phase Shifter.	25
11.	Upper Sideband.	26
12.	Top View.	30
13.	Bottom View	31
14.	Test Points and Internal Adjustment Locations	32
15.	Wideband Phase Shift Ckt Board - Layout & Test Points	33
16.	Wideband Phase Shift Circuit Board - Component Side	34
16a.	Component Location - Wideband Phase Shifter(lower).	Fold-out
16b.	Schematic - Wideband Phase Shifter(lower)	Fold-out
16c.	Component Location - Wideband Phase Shifter(upper).	Fold-out
16d.	Schematic - Wideband Phase Shifter(upper)	Fold-out
17.	Test Setup #1	35
18.	Test Setup #2	36
19.	Test Setup #3	41
	Schematic - Power Supply.	Rear-Part I
	Schematic - Balanced Modulators, Ckt Card A12	Rear-Part I
	Schematic - Model SD101A Dynamic Analyzer	Rear-Part I

SECTION I

GENERAL INFORMATION

1-1. INTRODUCTION.

The Dynamic Analyzer is a newly developed multipurpose instrument offering exceptional application versatility in the fields of vibration, acoustical and electrical analysis and measurement. Essentially, the analyzer is a frequency-tuned bandpass filter which is frequency-tuned inherently, without depending upon an internal servo, frequency to DC conversion, or phase-lock principles for its unique operation. The center frequency of a selected passband is continuously and precisely tuned to track a frequency from an external source. Figure 1 illustrates the concept of operation.

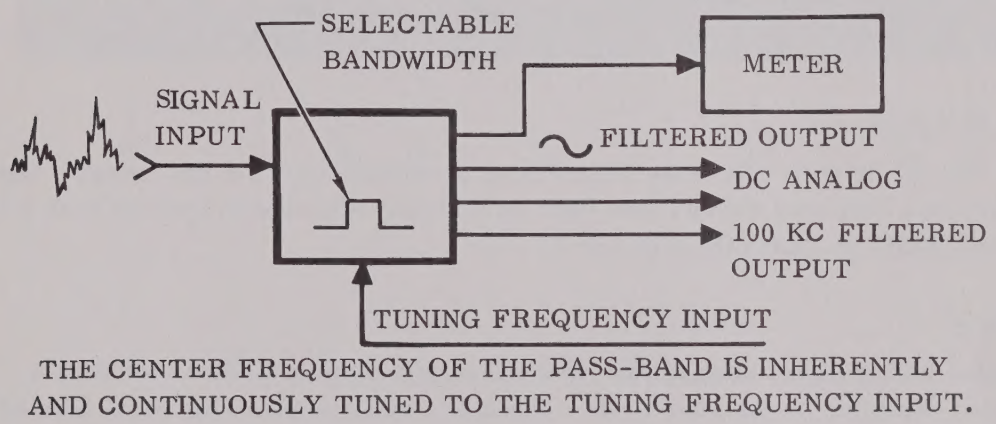


Figure 1. Concept of Operation

The frequency to which the SD101A is to be tuned is applied to the tuning frequency input. The center frequency of the selected passband is then virtually instantaneously tuned to this external frequency and as the tuning frequency input varies in frequency the center frequency of the passband continuously tracks the tuning signal frequency. The signal to be filtered is applied to the signal input of the analyzer and the SD101A provides four outputs representing data signals falling within the passband: (1) a meter; (2) a DC analog and (3) a filtered signal output and (4) a 100 KC filtered output.

1-2. GENERAL DESCRIPTION.

The instrument is packaged on a 7" × 19" standard panel and a chassis that extends 14" behind the front panel. The chassis has bottom and top dust covers which are

perforated for ventilation and are easily removed during maintenance. The top cover should be removed when the equipment is mounted in a closed console. The front panel (figure 2) contains the necessary operating controls, meters, calibration controls and input-output jacks to perform routine calibrating and operating functions. The following is a list of the front panel items and a brief description of their functions.

Power Switch

This selector applies power to the instrument. The STANDBY position applies power to the power supply, the tube filaments and to the ovens for the oscillator crystal and crystal filters. The amber light above the POWER switch denotes the standby position. The ON position of the POWER switch applies B+ to the tubes, and is denoted by a green light.

Signal Input

The signal that is to be analyzed or filtered is applied to these terminals. This input is paralleled to a connector on the rear of the equipment for use when rear wiring is desired.

Overload Indicator

The light located directly above the Signal Input terminals informs the operator when a circuit overload condition exists. The light is normally adjusted to operate with a crest factor (peak/RMS) of approximately 4 to 1.

Tuning Input

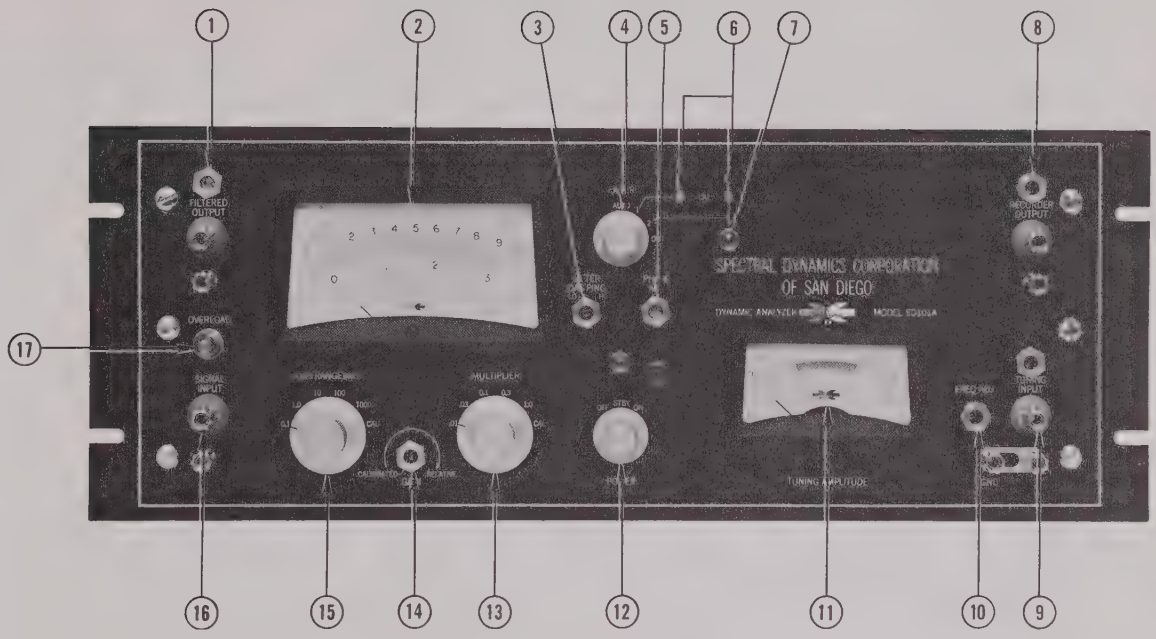
The external tuning signal used to tune the analyzer is applied to these terminals. This input is also available on the rear of the chassis. The front panel terminal labeled GND is connected to the chassis and the black terminal is connected to circuit ground. The instrument may be operated in the floating or non-floating mode depending on the connection of the terminal shorting link.

Tuning Amplitude Meter

The small meter displays the amplitude of the tuning signal input. A red band on the face of the meter provides a range of the proper operating level. This level can be adjusted by use of the screwdriver adjustment located directly above the tuning input terminals.

Frequency Adjust

This screwdriver adjustment (located between the tuning amplitude meter and the tuning input terminals) is used to adjust the reference oscillator frequency to the center frequency of the crystal filter. It is used during routine calibration procedure.



1 FILTERED SIGNAL OUTPUT
2 SIGNAL METER
3 METER DAMPING
4 FILTER SELECTOR
5 PHASE ADJUST
6 FILTER NORMALIZING POTENTIOMETERS
7 CROSSOVER INDICATOR
8 RECORDER OUTPUT
9 TUNING SIGNAL INPUT
10 FREQUENCY ADJUST
11 TUNING AMPLITUDE METER
12 POWER SWITCH
13 MULTIPLIER SELECTOR
14 GAIN ADJUST
15 RANGE SELECTOR
16 SIGNAL INPUT
17 OVERLOAD INDICATOR

Figure 2. Front Panel

Filter Selector

Used to manually select the desired plug-in crystal filter, or to provide for automatic bandwidth switching (AUTO position. See SD21 manual). The OUT position connects the input signal directly to the Filtered Signal Output terminals, completely bypassing the analyzer.

Filter CAL adjustments

An output adjustment is provided on the front panel for each filter. They are required to normalize the insertion loss of the plug-in crystal filters and thus establish the correct overall gain of the analyzer.

Crossover Indicator

The amber lamp located directly below the number two filter CAL adjustment is the filter crossover indicator. It is illuminated in either the manual or the automatic operating mode when filter two is selected.

Meter Damping

The screwdriver-adjustable switch located below the filter selector allows the operator to select HIGH or LOW damping circuits for the meter.

Phase Adjustment

The screwdriver phase control located adjacent to the Meter Damping switch is used to adjust the input to output phase angle or the relative phase between units in a multichannel system. This control is also used in cases where the SD101A is used in sine-reject applications. It provides a phase adjustment of approximately 115 degrees. If the desired phase adjustment cannot be obtained by this control, the Phase Invert switch located on top of the chassis can be switched to provide an additional 180-degree phase shift.

Range Selector

The RANGE switch is calibrated in volts (RMS) and operates the attenuator on the input of the instrument. The amplitude of the incoming signal should not exceed the selected range. In the CAL position, a calibration signal is applied internally to the instrument.

Multiplier Selector

The MULTIPLIER switch operates an attenuator just preceding the meter amplifier. The combination of the readings on the switch and the RANGE selector provides the operator with the selected meter range. When performing the internal CAL procedure the MULTIPLIER should be placed in the CAL position.

NOTE

CAL and 1.0 on the multiplier are common internally.

Signal Meter

The signal meter contains three scales that are selected by use of the RANGE and MULTIPLIER selectors discussed above. One scale is calibrated in DB while the other two are calibrated in RMS voltage.

Gain Adjust

This screwdriver adjustment is used to adjust the gain of the system during routine calibration procedure or when making relative amplitude measurements. When making relative measurements the gain control provides an 18 DB range of adjustment.

Filtered Signal Output

The filtered signal output is the signal amplitudes and frequency or frequencies contained in the passband of the instrument. The output level can be adjusted as desired by the adjacent screwdriver control. This output is also available from a rear connector.

Recorder Output

A DC voltage, proportional to the average amplitude of the signals contained in the passband is available at these terminals. The DC level is adjustable by use of the screwdriver adjustment directly above the terminals. The recorder output is available from a rear connector.

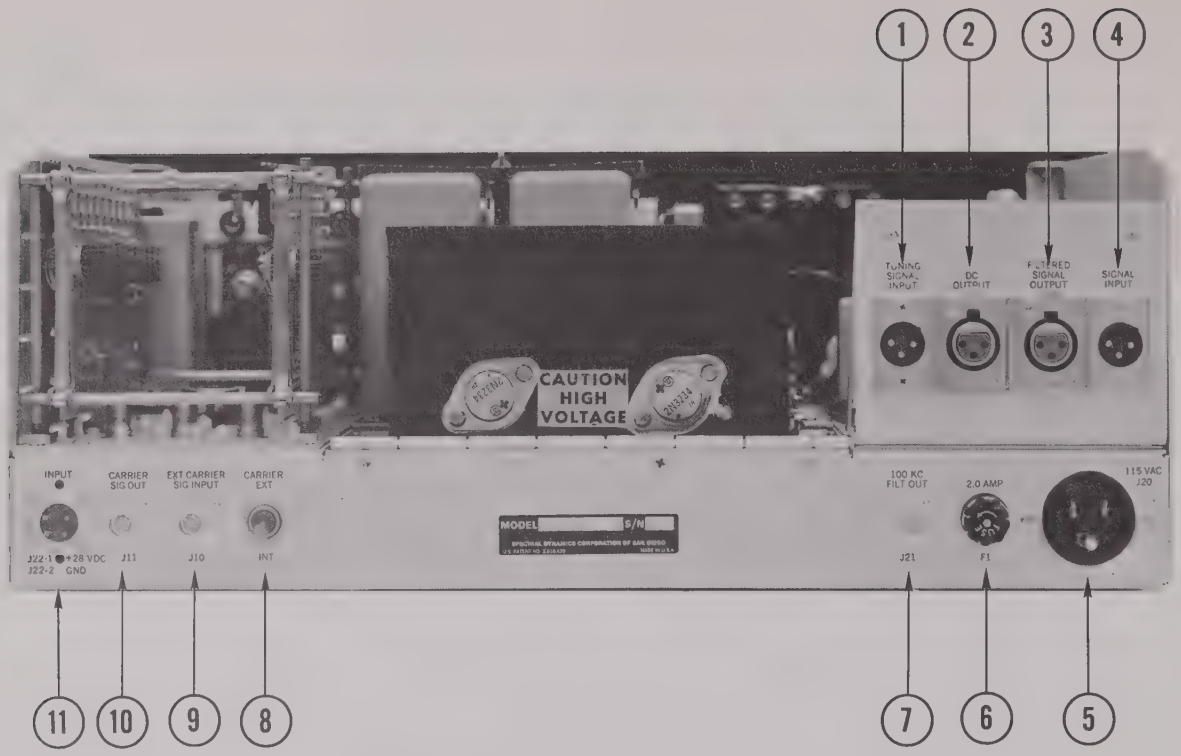
In addition to the connectors that are paralleled to the input and output terminals on the front panel, the following items are also located on the rear of the chassis: (See figure 3.)

Carrier Selector

The toggle switch is used to select the internal carrier signal, produced by the reference oscillator and tuning signal, or an external source. In the external position, this switch also disconnects B+ from the carrier converter section.

External Carrier Input

This BNC-type connector is provided to facilitate the use of an external carrier signal for tuning the SD101A. For example, two SD101A Analyzers can be tuned by a common source simply by connecting the CARRIER OUTPUT of the first SD101A to the EXTERNAL CARRIER INPUT of the second SD101A and switching the CARRIER SELECTOR of the second SD101A to the EXT position. Then with a tuning signal applied to the TUNING INPUT of the first SD101A, both SD101A Analyzers become tuned by a common carrier signal.



1 TUNING SIGNAL INPUT (J8)
2 DC OUTPUT (J6)
3 FILTERED SIGNAL OUTPUT (J5)
4 SIGNAL INPUT (J7)
5 POWER INPUT (J20)
6 FUSE (F1)
7 100 kHz FILTERED OUTPUT (J21)
8 CARRIER SELECTOR (S4)
9 EXTERNAL CARRIER SIGNAL INPUT (J10)
10 CARRIER SIGNAL OUTPUT (J11)
11 28 VDC INPUT (J22)

Figure 3. Rear Chassis View

28VDC Input (J22)

Available as optional equipment are proportional-control type filters designated as Model SD100APC, and proportional-control 100 kc crystal ovens. If these proportional-control type devices are used, suitable dc power must be supplied through connector J22. Each filter oven requires approximately 750 ma at room temperature turn-on, decreasing as the filters warm up. Starting current for the crystal ovens is approximately 150 ma. Power supply voltage should be 28 volts dc, plus or minus 1 volt, with plus or minus 0.5% regulation or better. Note: Observe polarity; pin 1 is positive and pin 2 is negative. Pin 2 is internally connected to circuit ground. If the SD101A is to be operated in the "floating" mode, (removal of the front panel shorting link), the dc power supply connected to J22 must also be "floated".

1-2. GENERAL DESCRIPTION (Cont'd)

Input/Output Connectors

The four input/output connectors located on the rear of the chassis are in parallel with the front panel input/output terminals.

Fuse

115 volts ac operation - 2 A, slo-blo type.
230 volts ac operation - 1 A, slo-blo type.

Power Input

The power input receptacle accepts a standard 3 prong type power plug.

Carrier Output

BNC type connector for multi-channel systems. An example of its use is given in the explanation for External Carrier Input.

1-3. SPECIFICATIONS

Frequency Range: 2 - 25,000 Hz

Useful Frequency Range: 1 - 30,000 Hz

Frequency Response:

Recorder

±0.25 dB over operating frequency range.

Meter

±2% of full scale

Filtered Signal Output

±0.25 dB from ½ BW to 10 kHz; response falls off gradually above 10 kHz down approximately 1 dB at 25 kHz.

Notes: (1) The operating frequency range is defined as the frequency equal to ½ the bandwidth of the filter in use to 25 kHz.

A filter having a bandwidth of 5 Hz, the operating frequency range would be ½ BW = 2.5 Hz to 25 kHz. If the BW is 20 Hz, operating frequency range is 10 Hz to 25 kHz.

(2) The SD101A may be used below the frequency equal to ½ BW if some degradation in performance is acceptable.

1-3. SPECIFICATIONS (Cont'd)

Dynamic Range:	Meter Circuit 60 dB Filtered Signal Output 60 dB Linear d-c Output 40 dB
Residual Noise:	60 dB below full output; with input terminals shorted.
Linearity:	Meter Circuit ±3% of F.S. DC Output ±0.25 dB FSO ±0.25 dB, 40 dB continuous range
Sensitivity: (Range)	1 mV - 1000 V
Input Impedance:	1 MΩ
Tuning Signal:	0.2 V rms minimum input required (sinusoidal with less than 5% distortion). Allowable amplitude variation approximately 7 dB.
Selectivity:	Accommodiations for two plug-in crystal filters. Standard bandwidths available for 2, 5, 10, 20, 50 and 100 Hz. The shape factor (60 dB/3 dB bandwidth) of each filter is nominally 4 to 1.
Calibration:	Internal reference.
Tracking Rate:	In excess of 20,000 Hz/sec.
Outputs:	(1) Recorder 0-1 Vdc into 100 kΩ . (2) Filtered signal adjustable; 10 V rms maximum into 10 kΩ .
Power:	115/230 Vac, 50/60/400 Hz, 120 W.
Inputs/Outputs:	Input/output terminals on the front panel are in parallel with input/output connectors on rear of chassis.
Size:	7" high, 19" wide, 14" behind panel (17,8 cm x 48,3 cm x 35,6 cm)
Shipping Weight:	34 LBS. (15,4 kg)

SECTION II

OPERATING INSTRUCTIONS

2-1. PRELIMINARY OPERATION CHECKS.

Meter Mechanical Zero

Check the meter mechanical zero. If the pointer does not rest directly over the zero with the power off, proceed as follows: A stable adjustment can only be made when the direction of pointer travel is opposite to the direction of rotation of the adjusting screw. The adjusting screw may be turned in either direction; however, the most effective method is to turn the screw clockwise until the pointer swings up-scale and then starts to swing down-scale toward zero. Continue turning the screw clockwise until the pointer (now moving to the left) is directly over the zero mark. If the screw is turned too far, continue turning clockwise until the pointer is again traveling down-scale toward zero. Tap the meter lightly to avoid any friction in the movement from giving a false indication of zero.

Carrier Switch

Check to see that the carrier INT/EXT toggle switch located on the rear of the unit is in the INT position.

Installation of Filters

Loosen the Camloc fasteners holding the top cover in place by turning the fasteners one-half turn counterclockwise. Rotate cover back (cover is rear-hinged), exposing the interior of the equipment. Plug in the crystal filters in the octal sockets marked A1 and A2 located on top of the chassis. A1 and A2 correspond to the front panel filter selector, Positions 1 and 2, respectively. Install narrowest filter in socket A1, wider filter in socket A2.

Filter CAL Potentiometers

The filter CAL potentiometers are multi-turn trimpots located on the front panel near the filter selector switch. The left-hand potentiometer adjusts the output of filter A1 and the right-hand potentiometer adjusts A2. The insertion loss normally varies between different filters; therefore, the SD101A must be recalibrated each time a different filter is installed.

2-2. OPERATION.

Filter Center Frequency Alignment and Sensitivity Calibration.

In the self calibrating mode, the unit's sensitivity is compared against the voltage output of an internal zener diode reference operating at the line frequency. The filter center frequency alignment relative to the tuning frequency, as well as the sensitivity calibration, is performed as follows:

a. Turn on power and allow unit to warm up approximately 45 minutes.

b. Turn RANGE and MULTIPLIER selectors to CAL position. This operation connects the internal reference to the input of the analyzer, and provides an internal tuning signal to the unit.

c. Turn the front panel GAIN control fully counterclockwise to the CALIBRATED position.

d. Turn FILTER switch to Filter 1.

e. Adjust the FREQUENCY control for a peak indication on the signal meter.

f. Adjust the Filter 1 CAL potentiometer for a meter reading of 7.

g. Select the broader filter (Filter 2) and without re-adjusting the FREQ control, turn the Filter 2 CAL potentiometer to obtain a meter reading of approximately 7 on the meter.

h. Turn RANGE and MULTIPLIER switches to appropriate positions (see para 2-3).

i. Apply the tuning frequency and data signal to their proper front or rear connectors. Adjust the tuning signal level control for centerline on the tuning meter.

2-3. SETTING THE RANGE AND MULTIPLIER SWITCHES.

Start measurements with the MULTIPLIER switch in the 1.0 position. Rotate the RANGE switch to obtain an up-scale reading. The purpose of this is to utilize the full dynamic range of the instrument. The filtered signal output is only affected by the RANGE control; therefore, the signal-to-noise ratios are primarily dependent on the RANGE setting.

CAUTION

This input level should not exceed the range control volts RMS. Higher values can overload the input amplifier. The Overload Indicator will indicate an overload condition.

The unit will withstand crest factors (peak/RMS) of approximately 4 to 1 when operating with the maximum RMS input. This ratio goes up proportionally as the input level is less than the range (RMS).

EXAMPLE: Range switch set at 1V RMS - input level 0.5V RMS. The input amplifier will now handle crest factors of 8 to 1. This becomes a factor when dealing with random or sine random-type of input signals. However, clipping the large transient peaks of a random signal will not appreciably affect the accuracy of measurement.

2-4. MAKING RELATIVE MEASUREMENTS.

When observing relative levels on the meter, the front panel GAIN control can be used to adjust the reading over an 18 DB range. Adjust for a full-scale reading with the MULTIPLIER on the 1.0 position. Re-establishing the instrument calibration on an absolute basis can be accomplished by rotating the gain control fully counterclockwise to the CALIBRATED position.

2-5. USE OF INTERNAL CAL SIGNAL.

The internal calibration signal applied to the input amplifier of the SD101A is used to perform filter alignment and sensitivity standardization of the SD101A.

In addition, the calibration signal provides a means for making single-point calibration of auxiliary readout equipment such as X-Y recorders, vibration meters, etc.

With the RANGE and MULTIPLIER in the CAL position a fixed-level 60-cycle tuning signal is applied to the Analyzer Tuning input, disconnecting the external tuning signal. A preset square wave with an equivalent fundamental sinusoidal amplitude of 70 MV RMS is connected to the input amplifier directly, bypassing the input range attenuator.

With the SD101A properly peaked and adjusted (Paragraph 2-2), the amplitude of a selected component of the input signal can be determined from the meter by multiplying the RANGE setting X MULTIPLIER setting = volts full scale.

When the SD101A is in CAL, output signals are obtained representing the output levels which would be produced by a 70 MV RMS signal applied to the input amplifier. Since an input signal must pass through the input RANGE switch the CAL signal represents a .7X range position during operation.

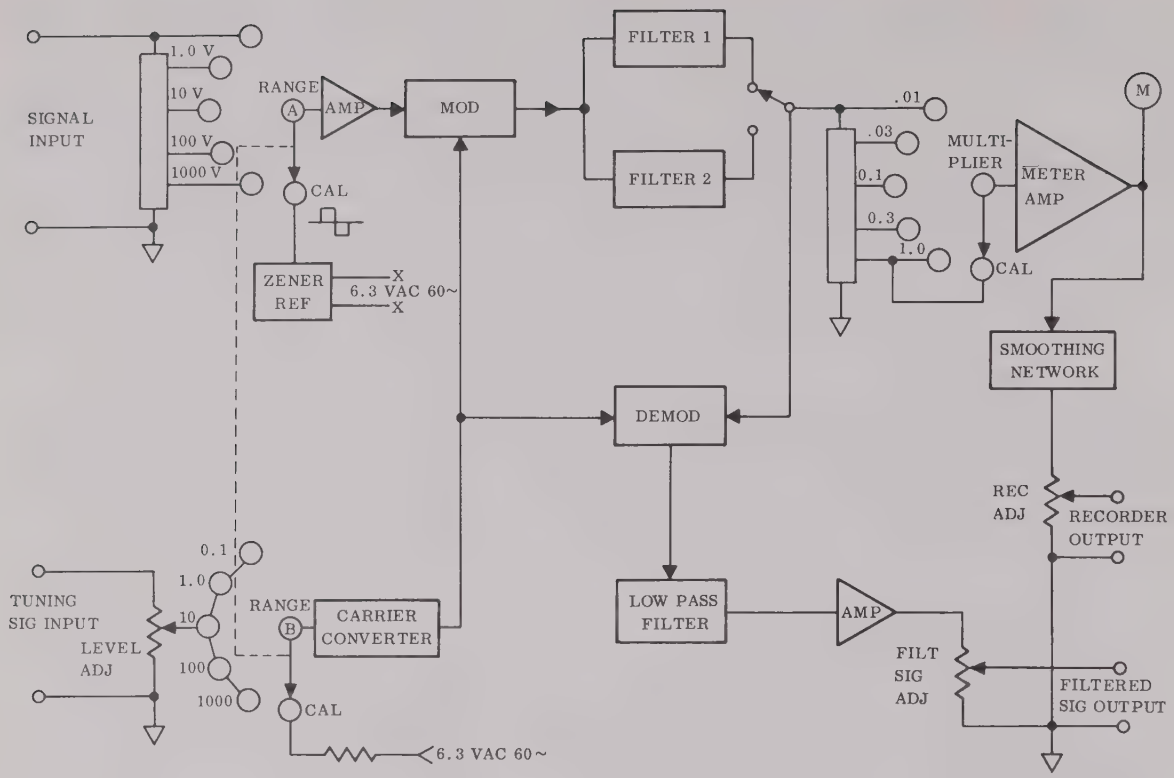


Figure 4. Block Diagram Showing CAL Circuits

NOTE

The Range Switch affects all outputs (Meter, Recorder, Filtered Signal). The Multiplier only affects the Meter and Recorder Circuits.

The MULTIPLIER changes the meter and recorder sensitivity 10 DB/step. An equivalent CAL output from the Recorder Circuit will increase 10 DB/step on the MULTIPLIER when in the operate mode. Therefore, the following formula is used for determining measured output levels when using the CAL signal before or after a data run to establish a single point calibration.

CAL Output Level = (Recorder Output) .7 X Operating RANGE setting X Operating MULTIPLIER Setting. (RMS Volts)

CAL Output Level = (Filtered Signal Output) .7 X Operating RANGE Setting (RMS Volts)

The RECORDER and FILTERED signal level adjustments can be used to adjust the output levels for scaling purposes.

These calibration signal outputs can be converted to g levels, velocity levels, etc., by dividing the above equations by the pickup sensitivity in V/g, V/IN./SEC, etc.

SECTION III

THEORY OF OPERATION

3-1. INTRODUCTION.

The SD101A can be considered to be divided into two relatively independent circuit sections:

1. Filtering and measurement section

2. Carrier Converter section

The two operate together to form the frequency-tuned bandpass filter concept. The basic theory of operation can be best explained by referring to the figure below.

The Carrier Converter functions to produce an output frequency that is the sum of the tuning frequency input and the 100 KC reference oscillator frequency. As an example,

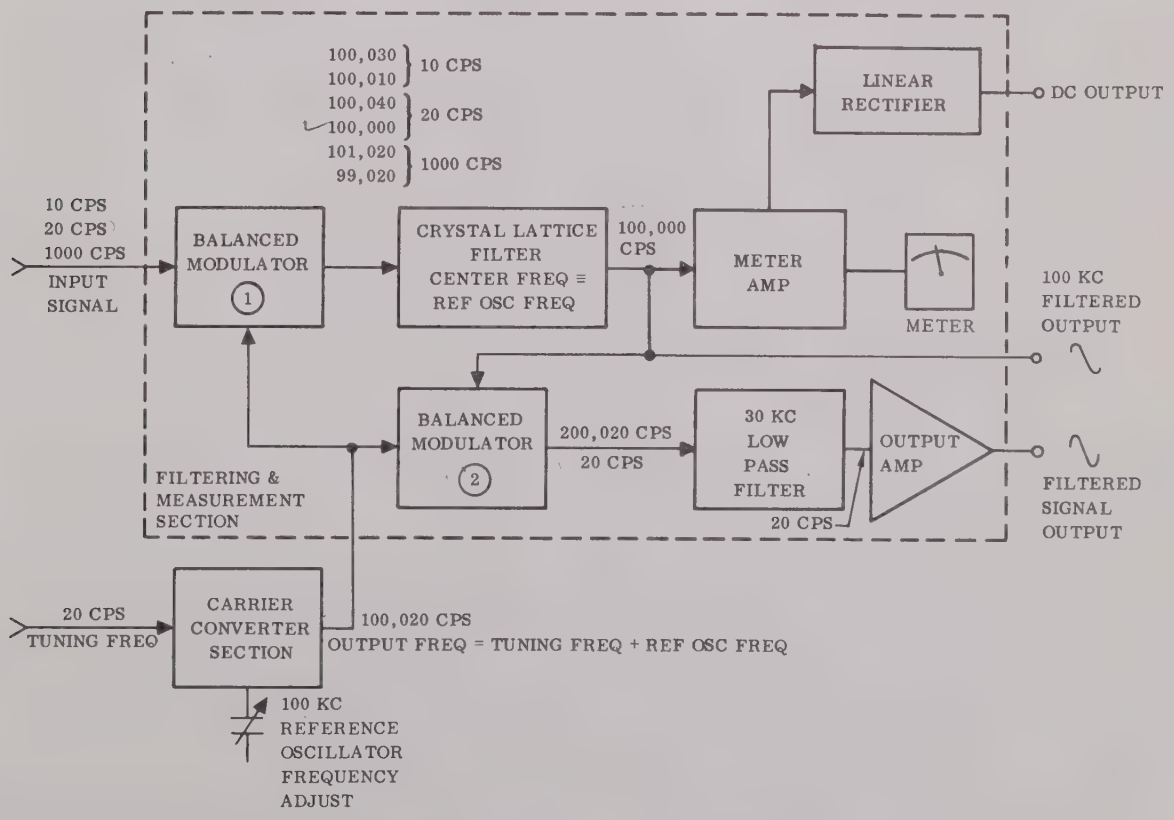


Figure 5. Simplified Block Diagram

with a 20 CPS tuning signal input the Carrier Converter produces an output of 100,020 CPS. Further, if the tuning frequency were to vary from 2 CPS to 25,000 CPS, the output from the Carrier Converter would be a frequency varying from 100,002 CPS to 125,000 CPS synchronously with the input tuning signal.

The frequency adjustment on the Reference Oscillator varies the reference frequency slightly so that the center frequency of the filter and reference oscillator frequency can be adjusted to the same frequency. The output of the Carrier Converter is then used to drive two (2) balanced modulators in the filtering and measurement section.

To show that the SD101A is adjusted to pass only frequencies lying within the passband of the filter, the following example is used:

Assume a complex signal applied to the input of the SD101A, consisting of three frequencies with different amplitudes - 1,000 CPS, 10 CPS, 20 CPS. Assume the Analyzer has a 10 CPS bandwidth filter.

Next, assume a tuning frequency of 20 CPS is applied to the tuning input terminals. The output of the Carrier Converter will be 100,020 CPS. The 100,020 CPS signal is applied to the balanced modulators 1 and 2. The output of balanced modulator 1 will essentially be the sum and difference of the signal frequencies and the Carrier Converter frequency. Since the Carrier Converter level is constant for all practical purposes (it can be considered constant since it is only supplying the switching voltage to the modulator), the amplitudes of the side band frequencies produced will be proportional to the amplitudes of the signal components at the Analyzer input. Therefore, at the output of modulator 1, we will have:

(100,020 + 20) = 100,040 CPS; (100,020 - 20) = 100,000 CPS; (100,020 + 10) = 100,030 CPS; (100,020 - 10) = 100,010 CPS; (100,020 + 1000) = 101,020 CPS; (100,020 - 1000) = 99,020 CPS

As can be seen from the side band components produced above, only the 20 CPS component amplitude will be passed through the crystal band pass filter, with all other components falling outside the pass band.

The output of the crystal filter is then passed to a meter circuit, indicating the amplitude of the signal passed by the filter and also to a rectifier circuit providing a DC output. Additionally, the output of the filter is fed to Modulator 2 where it is modulated with the Carrier Converter output. The output of Modulator 2 will be the sum and difference frequency of the Carrier Converter output frequency and the filter output frequency. Carrying the example through; the output of Modulator 2 will be (100,020 + 100,000) = 200,020 and (100,020 CPS - 100,000) = 20 CPS. The output of Modulator 2 is passed through a 30 KC low pass filter to reject the high frequency components, leaving only the 20 CPS component at the low pass filter output.

Next, injecting a tuning frequency of 1000 CPS would provide an output from the Carrier Converter of 101,000 CPS. This applied to Modulator 1 results in outputs of:

10 CPS input signal	20 CPS input signal	1000 CPS input signal
(101,010, 100,990);	(101,020, 100,980);	(102,000 and 100,000)

The 100,000 CPS signal will pass through the filter, and (1) its amplitude indicated by the meter circuit, (2) rectified to provide a DC analog output, and (3) fed to Modulator 2 where it is modulated with the 101,000 CPS signal, producing 201,000 CPS and 1000 CPS at Modulator 2 output. The 201,000 CPS component is rejected in the low pass filter, leaving only the 1000 CPS signal at the output.

Thus, from the above examples, it can be seen that the center frequency of the unit is tuned by the frequency of an external source.

Carrier Converter

The Carrier Converter produces an output frequency that is the sum of the tuning frequency and the reference oscillator frequency for tuning frequencies ranging from 2 CPS to 25 KCPS The process for accomplishing this is described below:

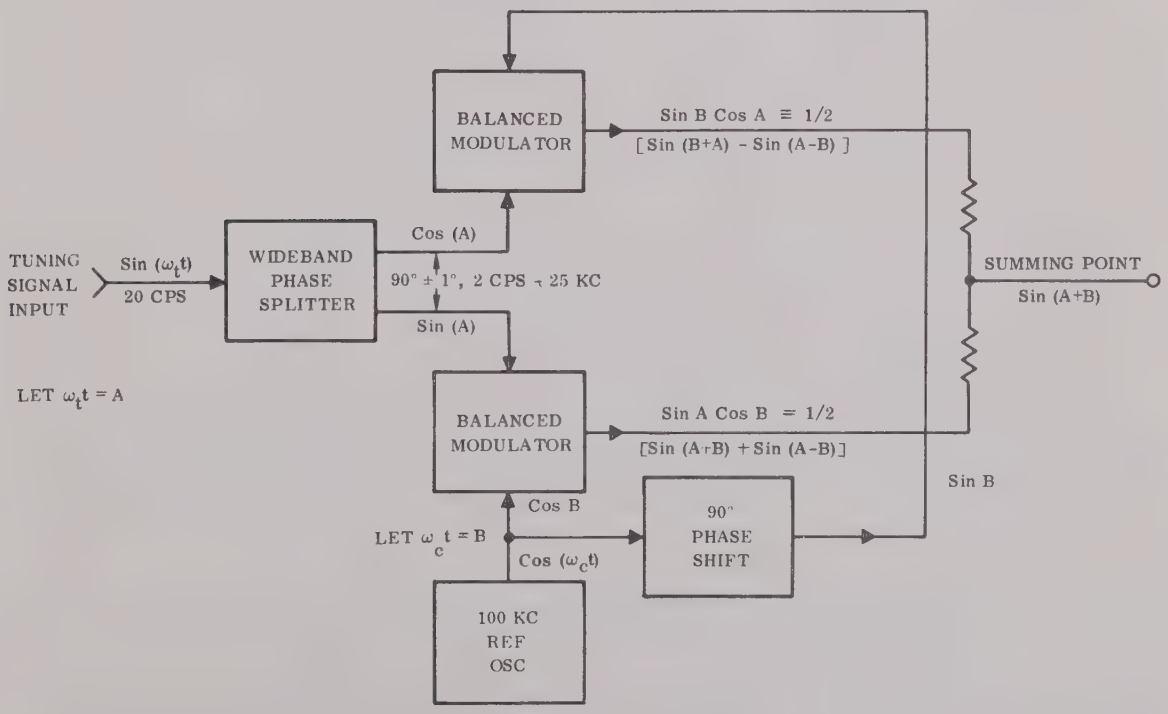


Figure 6. Carrier Converter

The tuning frequency is applied to a wide band phase shift network, producing two output signals equal in amplitude, but displaced in phase 90° with respect to each other. The outputs from the phase shifters are applied to two (2) balanced modulators where they modulate reference oscillator signals. The reference oscillator is also split into two (2) outputs that are 90° apart. The outputs from the balanced modulators are the sum and difference frequencies of the reference oscillator and the tuning frequency.

The modulator outputs are then linearly added together and the lower side band frequency is phase and amplitude cancelled, leaving only the sum of the input frequency plus the tuning frequency. Reference to figure 7 shows the trigonometric equations indicating how this is accomplished.

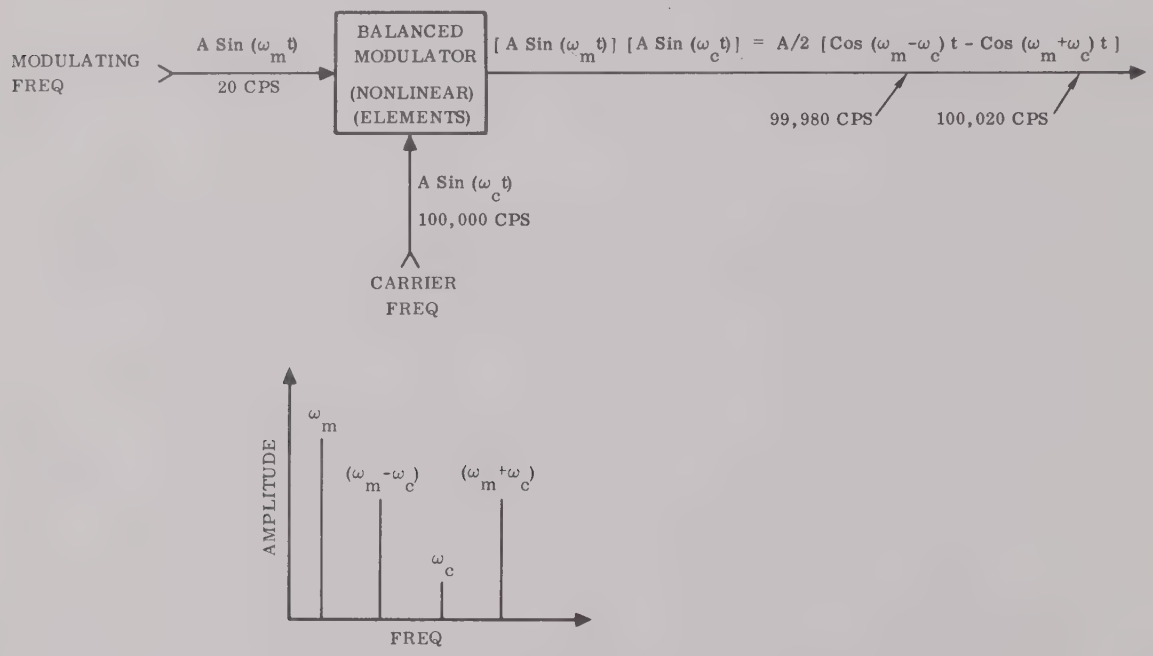


Figure 7. Balanced Modulator

A Word About Amplitude Modulation Theory:

Modulation is basically a process of multiplication.* To accomplish this process with simple analog devices involves the use of some non-linear element, such as diodes, vacuum tubes, varistors, etc.

The SD101A uses four (4) balanced modulators. The term "balanced" is used to denote a balancing or cancellation of the carrier frequency in the output of the modulator.

* A more thorough treatment of the subject can be found in any standard electronic engineering textbook.

As mentioned previously, modulation is basically a process of multiplication. Therefore, for illustration purposes, let us examine what occurs when two sine waves are modulated or multiplied in a balanced modulator:

Referring to the preceding figure, it is seen that two distortionless sine waves ideally multiplied together have a triognometric identity as shown, meaning that there are two (2) frequencies produced at the modulator output; i.e., the lower "sideband" frequency represented by the $(\omega_c - \omega_m)$ term in the trigonometric identity and the upper "sideband" frequency represented by the $(\omega_c + \omega_m)$ term.

The carrier frequency used in the SD101A is 100,000 CPS. The amplitudes of the side band signals on the output of a modulator are identical and proportional to the amplitude of the input signal amplitude, assuming that the amplitude of the carrier signal applied is constant.

In summary, when one signal is modulated by another, output frequencies are produced at the sum and difference of the two frequencies. If the carrier frequency is held constant in amplitude, the side band amplitudes are proportional to the input signal amplitude. If a complex wave is applied to a modulator, side band frequencies due to each of the signal frequency components are produced.

Figure 7 also shows an example of modulation of 100,000 CPS signal with a 20 CPS signal and the side band frequencies and illustrates graphically the distribution of the two side bands symmetrically about the carrier frequency ω_c.

Internal Calibration Circuit and Alignment of Reference Oscillator with Filter Center Frequencies:

Concept of the alignment procedure is seen by referring to figure 8a. The purpose of alignment is to adjust the filter center frequency to be centered at the tuning frequency. In concept this could be accomplished by tuning the filter with the same frequency as the data frequency. Since the center frequency of the pass band is supposed to be centered at the tuning frequency input, we could verify this by simply shifting the center frequency of the filter higher and lower in frequency with respect to the data frequency until the output from the filter reaches a peak. This concept is shown in figure 8a. Figure 8b shows the data frequency centered with the filter passband, and figure 8c shows the filter not aligned with the data signal.

Shifting the passband relative to the data signal is accomplished by shifting the frequency of the reference oscillator with respect to the center of the crystal filter passband. Therefore, the front panel adjustment labeled FREQ. is in effect shifting the center frequency of the passband relative to the tuning signal. Once the filter passband is set relative to the tuning frequency it will remain set over the frequency range.

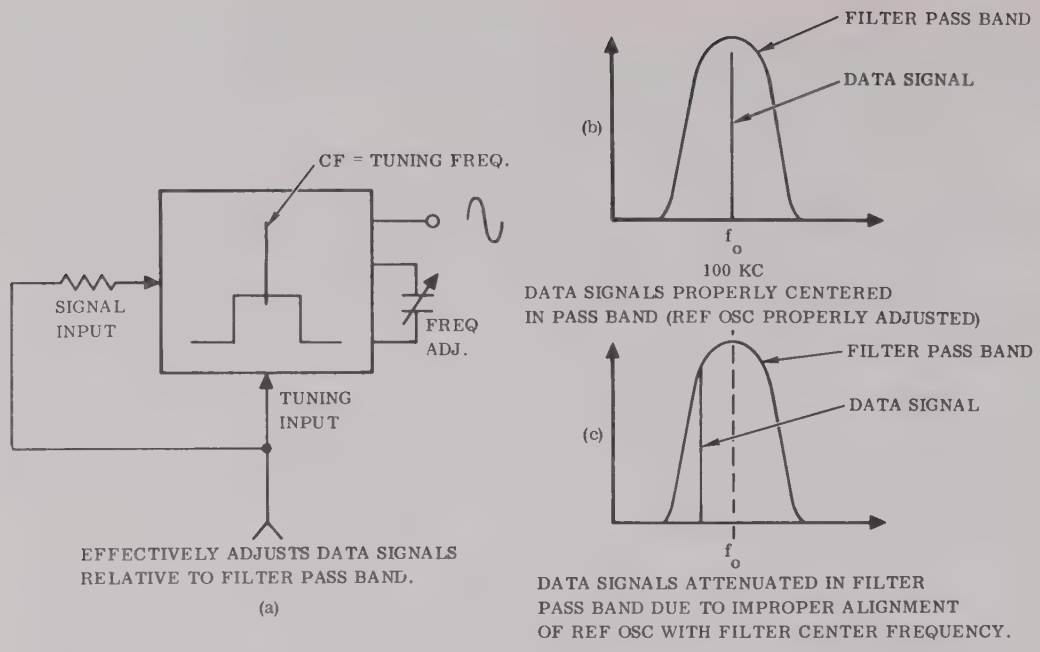


Figure 8. Alignment Procedure

From the above discussion, it is seen that it is desirable to minimize drift of the 100 KC filter center frequency relative to the reference oscillator frequency. To accomplish minimum drift on a long-term basis is the reason for the oven-controlled crystal filters and oven-controlled reference oscillator.

Shown in figure 9 is the practical circuit provided internally to not only adjust the center frequency of the filter, but apply a precise calibration reference signal to the input amplifier to set up and check the calibration of the instrument and any external readout devices.

When the RANGE switch is placed in the CAL position, the external tuning signal and signal inputs are disconnected from the unit. A portion of the 60 CPS filament voltage is fed into the tuning input and a 60 CPS square wave with a fundamental sine wave amplitude of 70 MV RMS is applied to the input amplifier. Adjusting the FREQ control for a peak aligns the filter with the tuning signal. Adjusting the filter CAL potentiometer for a meter reading of seven calibrates the unit.

3-2. CIRCUIT DESCRIPTION

A thorough understanding of the general theory and concept of operation, along with the following circuit description will help in the application of the instrument, as well as the potential trouble-shooting of the instrument.

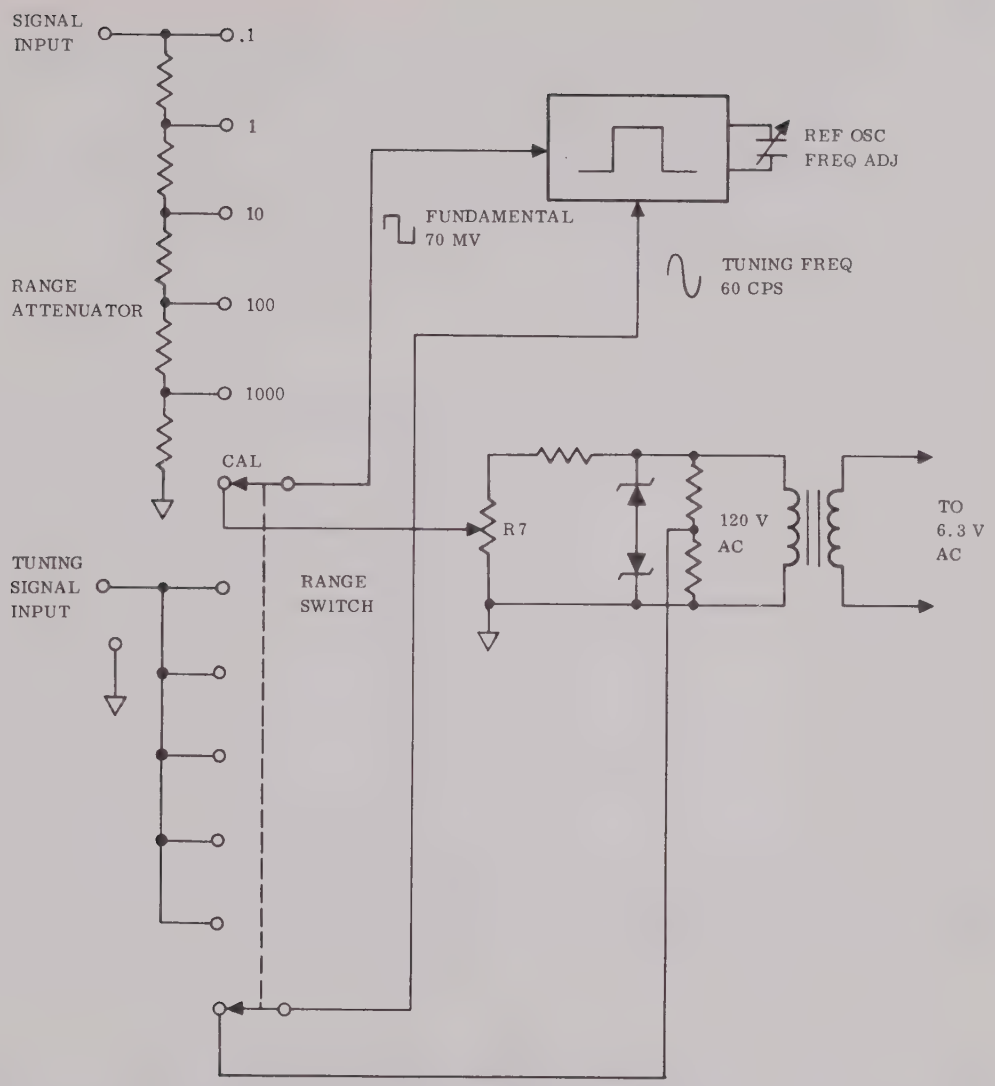


Figure 9. Internal Calibration

A. Filtering and Measurement Section

Range Switch (S1A, S1B)

The RANGE switch is a two-deck switch with two poles and six positions per deck. The input signal attenuator (S1A) is a one-megohm voltage divider with five positions for input signal attenuation ranges and the sixth position connects the 60 CPS reference voltage to the input amplifier. The second pole on S1A is used to disconnect the external tuning signal from the tuning signal input and apply an internal 60 CPS tuning signal. The second switch deck is used to activate the calibration signal circuit. This switching is done to eliminate 60 CPS hum from coupling into the input amplifier when the calibration circuits are not in use.

Calibration Circuit

Calibration circuit is made up of R6, R7, R8, R9, T1 and CR1. T1 is a filament transformer operated in reverse; i.e., the secondary is excited with 6.3V AC from the power supply filament source, thus producing 120 VAC at the primary. R8 is a current limiting resistor for the back-to-back reference diode, CR1. CR1 clips the 120V signal to a reference level of 12V peak-to-peak. R6 and R7 form a voltage divider to drop the 12V down to a 70 MV fundamental (equivalent sinusoidal amplitude). R7 is the CAL adjust potentiometer.

Input Amplifier (V1, V2, V3)

The input amplifier is a two-stage voltage feedback amplifier with a cathode follower output providing the driving signals to the signal modulator. The GAIN control varies the feedback around the amplifier and is set up to give an adjustment range of 18 DB. CR4 is used to prevent blocking and provides rapid overload recovery. The input amplifier has a fixed closed loop gain of 100 in the CALIBRATED position and will handle crest factors (peak/RMS) of 4 to 1. The gain is fixed at 100 by means of an internal potentiometer, R19, located between V2 and V3.

Signal Modulator (T2, C82, CR2A and B, R23, R24, R21)

The output of the input amplifier is connected to the signal modulator. The modulator is a shunt-type carrier balanced modulator. The transformer is specially constructed to minimize reactive unbalance, and the diode pair (CR2A and B) are matched in characteristics to minimize carrier leak. C82 is an adjustment to allow further reactance balancing. The primary of T2 is driven by V16, which is connected to the carrier converter output. The output of the signal modulator will be a half wave suppressed carrier double sideband signal.

Filter Driver (V4)

The output of the signal modulator goes to V4 which is a cathode follower used to provide impedance matching and isolation between the modulator and the crystal filters. A 3K resistor in series with the input to the filter provides proper input termination for the filter.

Filter Selector (S2A)

The FILTER selector switch is a four-position switch for selecting the desired filter bandwidth, manually or automatically, and to by-pass the SD101A altogether.

Crystal Filters

The crystal filters are multi-section crystal lattice filters, providing extremely narrow skirts. The filters have a shape factor defined as the ratio of the 60 DB bandwidth divided by the 3 DB bandwidth of nominally 4/1. This shape factor is the same on all

standard Spectral Dynamics' filters. Special bandwidths and shape factors can be supplied. The filters operate at a center frequency of 100 KC and require 3K resistive input and output termination. Signal sideband components falling within the filter bandwidth are passed through to potentiometers R28 and R29. R28 and R29 are used to equalize the relative insertion loss between the filters in the SD101A and additionally are used to establish the proper gain levels in the following amplifier stages. The 7.5K resistors shunting the potentiometers give proper load impedance to the crystal filters.

Tuned Amplifier (V6, V7)

This amplifier is used to remove spurious filter outputs and is a tuned, two-stage voltage feedback amplifier. R262 is used to adjust the gain of the stage to approximately 300.

Multiplier (R43 - R47)

The output of the Tuned Amplifier is routed to the Phase Adjust circuit that in turn drives the demodulator driver V5. The tuned amplifier output is also routed to the MULTIPLIER attenuator where the sensitivity of the meter and recorder circuits are controlled. The multiplier allows the meter to read levels 55 to 60 DB below a large input signal component.

Phase Adjust (T9, S8, C103, R261)

The phase adjust circuit provides a means of normalizing the input to output phase or the Filtered Signal Output phase relative to that of another unit such as another SD101A or SD1012 Tracking Filter. S8 is used to reverse the transformer (T9) leads thus providing a 180° phase shift. R261 is used to adjust the phase over a range of approximately 115 degrees.

Meter and Recorder Circuits (V8, V9, V10, M1)

The output of the multiplier is connected to a nuvistor tetrode (V8) to minimize capacitive loading of the multiplier. The tetrode is the input stage of a two-stage voltage feedback amplifier with a cathode follower output. The cathode follower drives the meter rectifier bridge and a rectifier (CR6) providing the DC analog output. The 100 KC signal level at the cathode follower output is approximately 20V peak-to-peak. Voltage feedback is derived from the cathode follower output for gain stabilization. R53 is the feedback resistor used to adjust the amplifier for a nominal gain of 80.

Recorder Output

The output of CR6 is connected to a smoothing filter comprised of C22, R59, and C23, with the output of the smoothing filter connected to an output level adjustment, R60. The output presents a variable output impedance to a load and will provide at least 1V DC into a 100K load for full-scale meter deflection. Since rectification of a 100 KC

signal is accomplished, short-time constant filtering is used giving the DC output rapid response with little ripple even at low input frequencies.

Demodulator-Demodulator Driver (V5)

The output of the tuned amplifier is connected via the Phase Adjust circuit to V5 which is a cathode follower used to drive one input of a ring demodulator. The other input to the demodulator is supplied from the carrier converter coupled to the demodulator through V16. The carrier converter output frequency varies from 100,002 CPS to 125,000 CPS, corresponding to the tuning frequency input. The output from the tuned amplifier represents the heterodyned filtered signal and combined with the carrier converter frequency in the demodulator produces an output which is the sum and difference frequencies between the two signals and an amplitude proportional to the heterodyned filtered signal. The lower sideband or beat frequency will be a signal that can vary in frequency from 2 CPS to 25 KC and the sum of the two will be a frequency varying from 200,002 to 225,000 KC. The amplitude of the signal component is proportional to the filtered signal component.

The demodulator output is then connected to a low pass filter network made up of L1, L2, L3, C1, C2, C3, C4, and R82. The low pass filter is used to remove the upper sideband component and has a nominal cutoff frequency of 30 KC, so that it will pass the signal components from 2 CPS as high as 30 KC with little attenuation and reject the high frequency components from the modulator. The output of the low pass filter is then connected into the filtered signal output amplifier.

Filtered Signal Output Amplifier (V17, V18 and V49)

The filtered signal output amplifier is a two-stage voltage feedback amplifier, with a cathode follower output coupled to the filtered signal output terminals. The amplifier has the capability of driving 10V RMS into a 10K load for full signal input. The output from the cathode follower (V49) is coupled to the output terminals through C101, a 50 mfd. capacitor. When connecting loads to the output of the SD101A, it must be kept in mind that best frequency response will be obtained with high impedance load. R253 sets the voltage gain of the amplifier to approximately 300.

B. Carrier Converter Section

The tuning signal is connected into the unit through a 100K potentiometer R90. The potentiometer is used to adjust the level of the tuning signal for proper circuit operation. The tuning signal is then routed to the RANGE control switch to facilitate application of a fixed internal tuning signal, making it unnecessary to disturb the setting of the tuning amplitude adjustment, during the calibration procedure. The tuning signal is next fed through the tuning signal amplifier which isolates the external circuitry from the printed circuit board.

Wide Band Phase Shifter

The wide band phase shifter consists of two printed circuit cards with the necessary tubes and components mounted on it and identified as the upper and lower printed circuit card. The cards are arbitrarily identified LOWER and UPPER for use as a guide for the mo ing and setting up of the cards.

The theory of operation can be described as follows: The phase shifter is made up of a combination of half lattice all pass sections. The upper board produces a relatively smooth phase shift versus frequency curve and the lower board produces the same characteristic phase shift only displaced by 90° (figure 10).

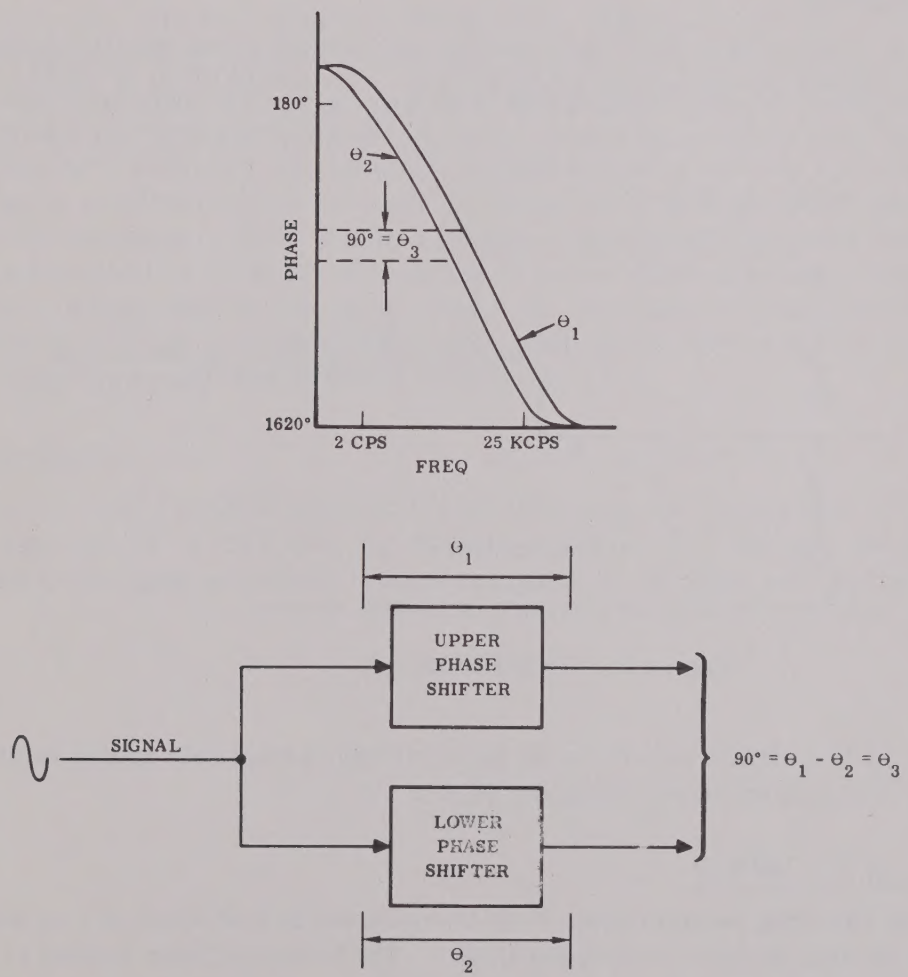


Figure 10. Wideband Phase Shifter

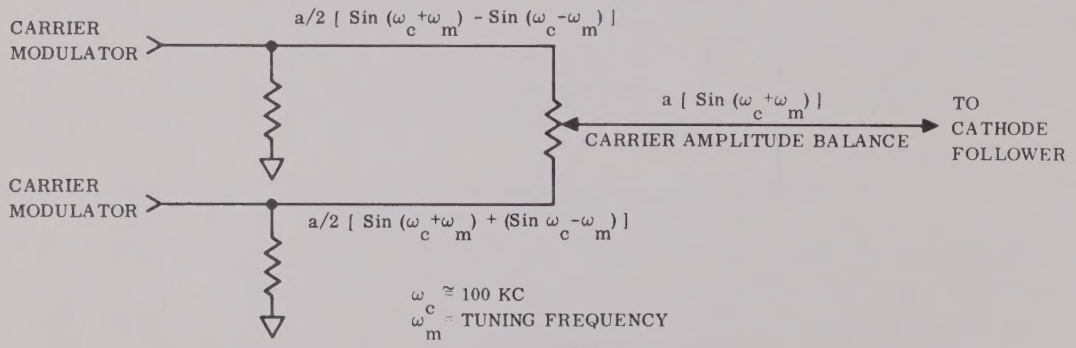
The output of the boards will be two signals equal in amplitude but displaced by 90° over the operating frequency range. A thorough treatment of the subject can be found in the following references:

1. D. Norgaard - The Phase-Shift Method of Single Sideband Signal Generation - Proc. IRE, December, 1956.
2. R. B. Dome - Wideband Phase Shift Networks - Electronics, Vol 19, Pages 112-115, December, 1946.

The outputs of the wideband phase shifter are connected to two modulators.

Carrier Modulators

The carrier signals are applied to the balanced ring modulators from the reference oscillator circuits. The reference oscillator circuits drive the modulators with 100 kHz signals shifted 90°. The output of the modulators are then linearily summed in A12R7, Carrier Amplitude Balance adjustment located on printed circuit card A12 - Assembly 10568-1.


CARRIER MODULATOR
a/2 [Sin (ωc+ωm) - Sin (ωc-ωm)]
a [Sin (ωc+ωm)]
CARRIER AMPLITUDE BALANCE
TO CATHODE FOLLOWER
CARRIER MODULATOR
a/2 [Sin (ωc+ωm) + (Sin ωc-ωm)]
ωc ≅ 100 KC
ωm = TUNING FREQUENCY

ADDITION OF MODULATOR OUTPUTS TO GIVE UPPER SIDEBAND

Figure 11. Upper Sideband

The addition of the two signals results in the upper sideband amplitude adding together and the lower sideband amplitudes adding out (figure 11).

Bandpass Filter (100 - 150 KC)

The output of the adjusting potentiometer R199 is connected to V40 which is a cathode follower amplifier used to drive a bandpass filter. The bandpass filter is used to remove spurious modulation components and provide a clean upper sideband signal to the carrier amplifier.

Carrier Amplifier (V41, V42)

The carrier amplifier amplifies the upper sideband signal to a suitable level for driving the signal modulator and demodulator. The output of the carrier amplifier is routed to the External, Internal Carrier switch. With the EXT/INT switch in the INT position, the carrier amplifier output is connected to the signal modulator/demodulator driver (V16). With the switch in the EXT position, the B+ supplied to the carrier converter section is disconnected and an external carrier signal can be connected into the connector marked EXT CARRIER INPUT. Driving the modulators from an external source is desirable when using two or more SD101A's slaved together.

Reference Oscillator-Phase Shifter-Carrier Modulator Drivers

The reference oscillator consists of V11, V12 and the plug-in reference oscillator crystal and oven. The oscillator is a Pierce-type. The frequency control C28, is used to adjust the frequency of the reference oscillator over a range of approximately ±15 CPS. The stability of the oscillator is ±.25 CPS and is maintained over long periods of time due to the oven-controlled crystal.

The output amplitude of the oscillator is controlled by C25 and C90. The oscillator output is connected to V14. V14 is a paraphase phase-shift amplifier with the phase shift determined by the R. C. half lattice output network. The lattice output is connected to a modulator driver, V15. The R.C. combination, adjustable with R73, is adjusted to produce a 90° phase shift between the output of V13 and the output of V15. The signal appearing across R72 is used to drive V13.

Power Supply

The power supply module provides 125 milliamps at 150 VDC, ripple 1 MV RMS(MAX.) and regulation of 0.05%.With the POWER switch on STBY the filament voltage is applied to the tubes and heater voltage is applied to the filter and oscillator ovens.